Tensile Properties and Integrity of Cleanroom and Low-modulus Nitrile Exam Glove Formulations

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Introduction

Disposable nitrile gloves are a common choice as a barrier to chemical and biological hazards; however, glove selection is complicated by the availability of several types/formulations. It is likely that the abundance or absence of plasticizers, oils, and/or fillers may affect glove integrity, as well as biomechanical performance (e.g tensile strength or modulus).

This study evaluated the tensile properties and physical integrity of two different nitrile exam glove types. It was anticipated that cleanroom gloves would not contain significant amounts of oil or plasticizer, which could contaminate surfaces within a controlled environment. In contrast, low-modulus gloves were expected to have a higher amount of plasticizer, which is used to reduce tensile strength and modulus.

Significance

Workplace protection factors and certifications have been developed and established for respiratory protection devices, but not for protective clothing such as disposable gloves. [1-2] Determination of those factors affecting whole-glove performance under work-use conditions will help in the development of improved materials performance and possible certification of disposable gloves. This would improve the protection provided to workers using disposable gloves as a barrier against chemical, physical, and biological hazards.

Materials & Methods

Six cleanroom and five low-modulus nitrile exam glove products were evaluated.

Water Leak Test (Glove Integrity)

A modified water-leak test (Figure 1) was used in this study. Stretching in the cuff region was restricted using a 3-inch long coupling between the glove and adjoining water column. This increased the water pressure in the rest of the glove and helped increase leak detection sensitivity.

The water leak test was standardized to detect a small 30-gauge needle hole in various regions of the glove. Adjusted water volumes ranged between 1 to 2 liters. Each glove was closely observed for leaks immediately following the introduction of water and then again after two minutes.

Figure 1. Modified Water Leak Test

Tensile Testing

Tensile strength was studied using the American Society for Testing and Material Method D 412. Horizontal and vertical samples (3" x 0.5") were removed from the palm regions using a cutting die. A total of 40 samples were analyzed using a tensiometer (Figure 2a and 2b) for each glove brand.

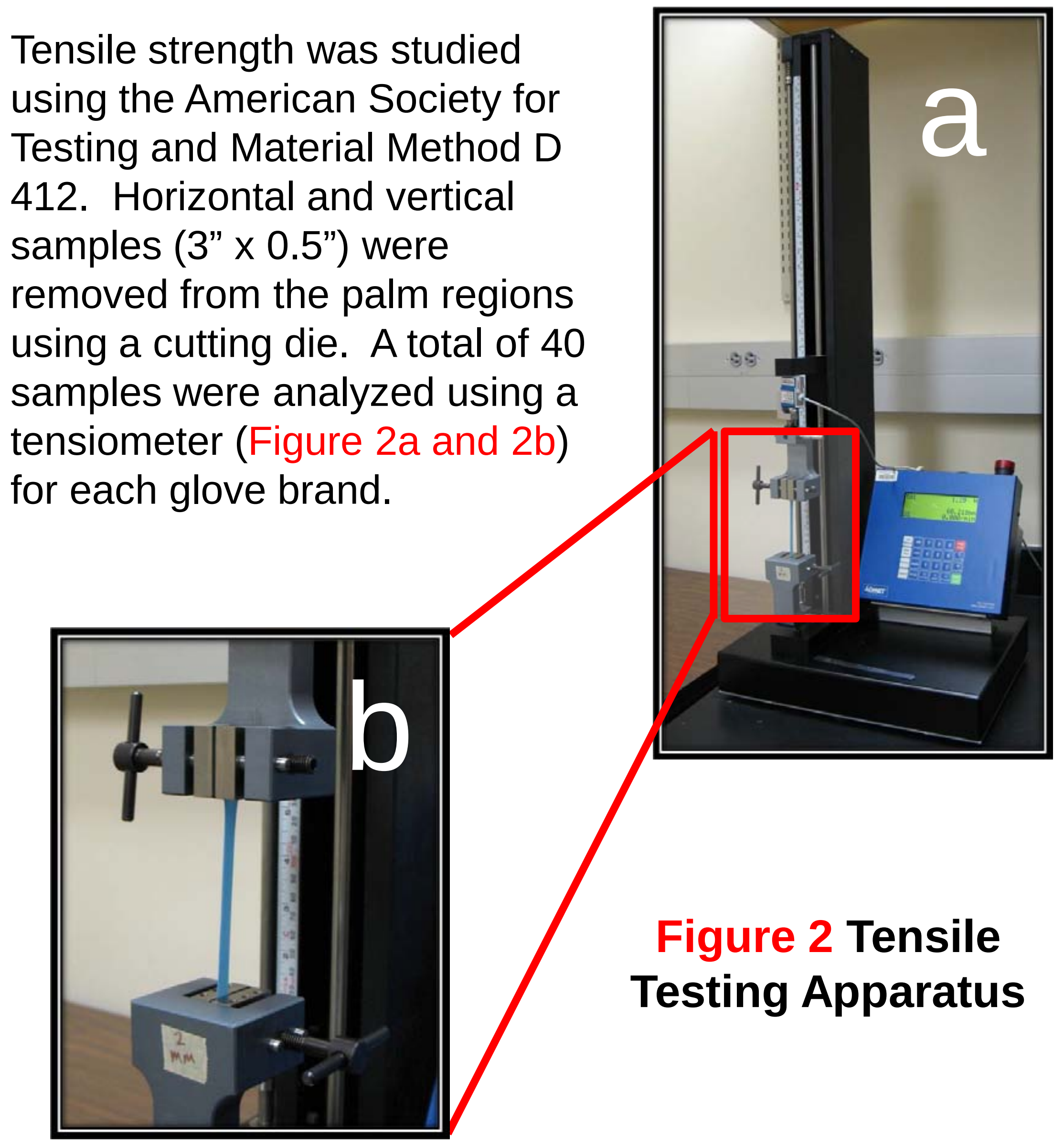

Figure 2 Tensile Testing Apparatus

Results ⇨

Physical and Mechanical Glove Properties

ID	Average glove thickness (mm)	Area Density (g/cm²)	Tensile Strength (MPa)	Elongation at Break (%)	Modulus 50-100% (MPa)	Maximum Modulus (MPa)	Leak Failures (%)
Cleanroom Gloves							
1	0.11 ± 0.01	11.1 ± 1.2	29.4 ± 5.2	544 ± 96	4.0 ± 0.9	8.6 ± 2.2	5.9
2	0.15 ± 0.03	14.1 ± 1.9	22.9 ± 3.1	785 ± 68	1.5 ± 0.3	5.1 ± 1.0	3.7
3	0.090 ± 0.006	9.2 ± 0.6	23.9 ± 9.1	710 ± 159	2.1 ± 0.4	4.7 ± 2.3	0.0
4	0.14 ± 0.03	13.9 ± 0.5	17.3 ± 3.7	712 ± 114	1.7 ± 0.1	3.4 ± 1.1	0.6
5	0.12 ± 0.02	12.1 ± 1.6	15.5 ± 3.8	647 ± 93	1.9 ± 0.4	4.4 ± 0.6	4.7
6	0.12 ± 0.01	11.7 ± 1.2	18.9 ± 2.8	868 ± 97	1.7 ± 0.2	3.1 ± 1.4	0.6
Group Average	**0.12 ± 0.02**	**12.0 ± 1.8**	**21.3 ± 5.1**	**711 ± 111**	**2.1 ± 0.9**	**4.9 ± 2.0**	**2.6 ± 2.5**
Low-modulus Gloves							
7	0.11 ± 0.01	11.1 ± 1.2	20.6 ± 6.0	681 ± 135	1.8 ± 0.3	5.1 ± 1.4	0.6
8	0.10 ± 0.01	9.4 ± 1.0	16.7 ± 4.4	766 ± 145	1.1 ± 0.1	3.5 ± 0.9	0.6
9	0.10 ± 0.02	9.8 ± 0.6	10.8 ± 3.3	724 ± 128	0.99 ± 0.04	2.5 ± 0.8	1.2
10	0.095 ± 0.009	9.7 ± 1.0	16.4 ± 5.1	656 ± 118	1.2 ± 0.1	3.4 ± 1.5	1.1
11	0.11 ± 0.01	11.0 ± 1.0	12.6 ± 5.0	665 ± 143	1.4 ± 0.2	2.4 ± 1.1	1.2
Group Average	**0.10 ± 0.01**	**10.2 ± 0.8**	**15.4 ± 3.8**	**698 ± 46**	**1.3 ± 0.3**	**3.4 ± 1.1**	**1.0 ± 0.3**

Chi-square Glove Type versus Glove Leaks

Glove Type	No leaks	Leaks	Total
Cleanroom	1,415 (96.92%)	45 **(3.08%)**	1,460 (100%)
Low-modulus	891 (99.00%)	9 **(1.00%)**	900 (100%)
Total	2,306 (97.71%)	54 (2.29%)	2,360 (100%)

Pearson chi-square = 10.797 (p = 0.001)

Correlation Analysis

	Glove Type	Leak failures	Tensile Strength	Modulus 50-100%	Max. Modulus	Area Density
Glove Type	----	-0.07	*-0.56*	**-0.71**	*-0.54*	*-0.63*
Leak Failures		----	0.05	0.08	0.09	0.05
Tensile Strength			----	*0.62*	**0.83**	0.17
Modulus 50-100%				----	*0.65*	0.25
Maximum Modulus					----	0.31
Area Density						----

Values shown are Spearman's rank order correlation coefficient (rho) with all $p \leq 0.03$.
Bold = strong association
Italic = weak to moderate association

Logistic Regression of Glove Failure by Experimental Variables

Variable	Odds Ratio	95% Confidence Interval	*p* value
Glove Type			
Low-modulus *	1.00		
Cleanroom	**3.15**	1.53 – 6.47	0.002
Glove Product (ID)			
Glove 6 *	1.00		
Glove 1	**10.04**	1.33 – 75.66	0.025
Glove 5	6.83	0.89 – 52.39	0.065
Tensile Strength ≥ 18 MPa	1.50	0.87 – 2.60	0.14
Elongation at Break	0.99	0.99 – 1.00	<0.001
Modulus 50-100% ≥ 1.7 MPa	2.00	1.14 – 3.52	0.016
Maximum Modulus ≥ 4 MPa	3.68	1.84 – 7.34	<0.001
Area Density ≥ 11 g/cm²	3.89	1.54 – 9.80	0.004

* Reference category
Bold = significantly more leaks than the reference category ($p \leq 0.05$)

Conclusions

On average, the leak failure rates were significantly different between the two glove types. The cleanroom gloves were about three times more likely to have leak failures than the low-modulus gloves. However, the correlation and logistic regression analyses indicated that tensile properties are not strongly associated with leak failures. From an infection control standpoint, the low-modulus gloves appear to be a better choice for protection. The observed variability between glove products and brands indicate that glove selection can not rely solely on glove type. Both maximum modulus < 4 MPa and area density < 11 g/cm² were associated with improved glove integrity.

References

1. NIOSH: "A Review of Gaps and Limitations in Test Methods for First Responder Protective Clothing and Equipment", January 31, 2005, [Online] Available at www.cdc.gov/niosh/npptl/pdfs/ProtClothEquipReview.pdf (Accessed Dec., 2005).
2. Brouwer, D.H. et al.: Concepts of skin protection: considerations for the evaluation and terminology of the performance of skin protective equipment. *Journal of Occupational and Environmental Hygiene* 2: 425 (2005).

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